WHAT IS CLAIMED IS:

1. An aerial image measurement method to measure an aerial image of a predetermined mark formed by a projection optical system, said measurement method including:

illuminating said mark with an illumination light and forming an aerial image of said mark on an image plane via said projection optical system; and

scanning a pattern forming member, which has at least one slit-shaped aperture pattern extending in a first direction within a two dimensional plane perpendicular to an optical axis of said projection optical system which width perpendicular to said first direction within said two dimensional plane serving as a second direction is set in consideration of at least one of a wavelength λ of said illumination light and a numerical aperture N.A. of said projection optical system, in said second direction within a surface close to said image plane parallel to said two dimensional plane, and photo-electrically converting said illumination light having passed through said aperture pattern and obtaining a photoelectric conversion signal which corresponds to an intensity of said illumination light having passed through said aperture pattern.

2. The aerial image measurement method according to Claim 1, wherein

said width of said aperture pattern in said second direction is set in consideration of both said wavelength λ

of said illumination light and said numerical aperture N.A. of said projection optical system.

3. The aerial image measurement method according to Claim 1, wherein

said width of said aperture pattern in said second direction is greater than zero, and equal to and under said wavelength λ of said illumination light divided by said numerical aperture N.A. of said projection optical system (λ/N.A.).

4. The aerial image measurement method according to Claim 3, wherein

said width of said aperture pattern in said second direction is equal to and under said (λ/N.A.) multiplied by 0.8.

5. The aerial image measurement method according to Claim 1, wherein

said width of said aperture pattern in said second direction is half a minimum pitch multiplied by an odd number, said minimum pitch being a pitch of a line and space pattern in a limit of resolution set by illumination conditions including properties of said illumination light and the type of said pattern.

6. The aerial image measurement method according to Claim 1, wherein

when a wavelength of said illumination light is expressed as λ and a numerical aperture of said projection optical system is expressed as N.A, said width of said aperture pattern in said second direction is set as $\{\lambda/(2N.A.)\}$ multiplied by an odd number.

7. The aerial image measurement method according to Claim 1, said measurement method further including:

obtaining a spacial frequency distribution by performing a Fourier Transform on said photoelectric conversion signal;

converting said spacial frequency distribution into a spectrum distribution of its original aerial image by dividing said spacial frequency distribution with a frequency spectrum of said aperture pattern that is already known; and

recovering said original aerial image by performing an inverse Fourier Transform on said spectrum distribution.

8. An optical properties measurement method to measure optical properties of a projection optical system, said measurement method including:

illuminating a predetermined mark with an illumination light and forming an aerial image of said mark on an image plane via said projection optical system;

scanning a pattern forming member, which has at least one slit-shaped aperture pattern with a predetermined slit width extending in a first direction within a two dimensional plane perpendicular to an optical axis of said projection optical system, within a surface close to said image plane

parallel to said two dimensional plane in a second direction which is perpendicular to said first direction, and photo-electrically converting said illumination light having passed through said aperture pattern and obtaining a photoelectric conversion signal which corresponds to an intensity of said illumination light having passed through said aperture pattern; and

obtaining optical properties of said projection optical system based on said photoelectric conversion signal.

9. The optical properties measurement method according to Claim 8, wherein

said mark consists of a line and space mark that has a periodicity in a direction corresponding to said second direction,

detection of said photoelectric conversion signal is repeated a plurality of times while changing a position of said pattern forming member in a direction of said optical axis, and

a predetermined evaluation amount that changes in accordance with a position of said pattern forming member in a direction of said optical axis is obtained, based respectively on a plurality of photoelectric conversion signals obtained in said detection repeated, and a best focal position of said projection optical system is obtained based on a largeness of said evaluation amount.

10. The optical properties measurement method according

to Claim 9, wherein

said evaluation amount is a contrast which is an amplitude ratio of a first order frequency component and a zero order frequency component of respective signals obtained by performing Fourier Transform respectively on said plurality of photoelectric conversion signals, and

a best focal position is to be a position of said pattern forming member in a direction of said optical axis which corresponds to a photoelectric conversion signal with said contrast maximized.

11. The optical properties measurement method according to Claim 9, wherein said method further includes detecting an image plane shape of said projection optical system by repeatedly performing detection of said best focal position on a plurality of points distanced differently from an optical axis of said projection optical system.

12. The optical properties measurement method according to Claim 9, said measurement method further including:

performing detection of said best focal position along an optical axis of said projection optical system repeatedly on a plurality of line and space patterns having a different pitch, and

obtaining a spherical aberration of said projection optical system based on a difference of said best focal position corresponding to each of said line and space patterns.

13. The optical properties measurement method according to Claim 8, wherein

forming of said aerial image and detection of said photoelectric conversion signal are repeatedly performed on an aerial image of said mark projected at different positions within an image field of said projection optical system, and

based on a plurality of photoelectric conversion signals obtained in said detection repeated, a position of an aerial image individually corresponding to said plurality of photoelectric conversion signals are respectively calculated, and at least one of a distortion and a magnification of said projection optical system is obtained based on said calculation results.

14. The optical properties measurement method according to Claim 13, wherein said mark includes at least one rectangular pattern which width in said second direction is larger than a width of said aperture pattern in said second direction.

15. The optical properties measurement method according to Claim 14, wherein a phase detection is performed so as to respectively detect a phase of said plurality of photoelectric conversion signals, and a position of each of said aerial images is calculated based on a result of said phase detection.

16. The optical properties measurement method according to Claim 14, wherein a position of each of said aerial images is calculated based on an intersection point of each of said

plurality of photoelectric conversion signals and a predetermined slice level.

17. The optical properties measurement method according to Claim 13, wherein said mark is a rectangular shape as a whole, and consists of a line and space pattern having a periodicity in said first direction.

18. The optical properties measurement method according to Claim 17, wherein a position of each of said aerial images is calculated based on an intersection point of said plurality of photoelectric conversion signals respectively and a predetermined slice level.

19. The optical properties measurement method according to Claim 8, wherein

said mark consists of a line and space pattern having a periodicity in a direction corresponding to said second direction, and

a coma of said projection optical system is obtained based on said photoelectric conversion signals.

20. The optical properties measurement method according to Claim 19, wherein said coma is calculated based on a calculation result, said calculation result on an abnormal line width value of each line pattern based on an intersection point of said photoelectric conversion signals and a predetermined slice level.

21. The optical properties measurement method according to Claim 19, wherein said coma is calculated based on a calculation result, said calculation result on a phase difference between a first fundamental frequency component of said photoelectric conversion signals corresponding to a pitch of each said line and space pattern and a second fundamental frequency component of said photoelectric conversion signals corresponding to an entire width of said line and space pattern.

22. The optical properties measurement method according to Claim 8, wherein

said mark is a symmetric mark having at least two types of a line pattern with a different line width arranged in a predetermined interval in a direction corresponding to said second direction, and

a coma of said projection optical system is obtained based on a calculation result, said calculation result on a deviation of symmetry of an aerial image of said mark calculated based on an intersection point of said photoelectric conversion signals and a predetermined slice level.

23. The optical properties measurement method according to Claim 8, wherein a width of said aperture pattern in said second direction is set in consideration of at least one of a wavelength λ of said illumination light and a numerical aperture N.A of said projection optical system.

24. An optical properties measurement method to measure optical properties of a projection optical system, said measurement method including:

illuminating a first mark in a state where said first mark is positioned at a first detection point within an effective field of said optical projection system to form an aerial image of said first mark, and measuring a light intensity distribution corresponding to said aerial image by relatively scanning a measurement pattern with respect to said aerial image of said first mark at a first position related to an optical axis direction of said projection optical system and photo-electrically converting light via said measurement pattern;

illuminating a second mark in a state where said second mark is positioned at a second detection point within an effective field of said optical projection system to form an aerial image of said second mark, and measuring a light intensity distribution corresponding to said aerial image by relatively scanning said measurement pattern with respect to said aerial image of said second mark at second position related to an optical axis direction of said projection optical system and photo-electrically converting light via said measurement pattern; and

obtaining a positional relationship between a first image forming position of said aerial image of said first mark within a plane perpendicular to said optical axis obtained by a result of said measurement of said aerial image of said first mark when said measurement pattern is at said first position of

said optical axis and a second image forming position of said aerial image of said second mark within a plane perpendicular to said optical axis obtained by a result of said measurement of said aerial image of said second mark when said measurement pattern is at said second position of said optical axis, and calculating a telecentricity of said projection optical system based on said positional relationship.

24. The optical properties measurement method according to Claim 23, wherein said first mark and said second mark are the same.

25. The optical properties measurement method according to Claim 23, wherein said measurement pattern is an aperture pattern which width in said scanning direction is set in consideration of at least one of a wavelength λ of said illumination light and a numerical aperture N.A of said projection optical system.

26. An aerial image measurement unit that measures an aerial image of a predetermined mark formed by a projection optical system, said measurement unit comprising:

an illumination unit which illuminates said mark to form an aerial image of said mark onto an image plane via said projection optical system;

a pattern forming member, which has at least one slit-shaped aperture pattern extending in a first direction within a two dimensional plane perpendicular to an optical

axis of said projection optical system which width in a second direction being perpendicular to said first direction is greater than zero, and equal to and under said wavelength λ of said illumination light divided by said numerical aperture N.A. of said projection optical system (λ/N.A.);

a photoelectric conversion element which photo-electrically converts said illumination light having passed through said aperture pattern, and outputs a photoelectric conversion signal corresponding to an intensity of said illumination light; and

a processing unit which scans said pattern forming member in said second direction within a surface parallel to said two dimensional plane in the vicinity of said image plane in a state where said mark is illuminated by said illumination unit and said aerial image is formed on said image plane, and measures a light intensity distribution corresponding to said aerial image based on said photoelectric conversion signal output from said photoelectric conversion element.

27. An optical properties measurement unit that measures optical properties of a projection optical system, which projects a pattern on a first surface onto a second surface, said unit comprising;

an aerial image measurement unit according to Claim 26; and

a calculation unit which calculates said optical properties of said projection optical system based on a photodetection conversion signal obtained upon measurement

of a light intensity distribution by said aerial image measurement unit.

28. An exposure apparatus that transfers a circuit pattern formed on a mask onto a substrate via a projection optical system, said exposure apparatus comprising:

a substrate stage which holds said substrate; and

an aerial image measurement unit according to Claim 26 which has an arrangement of said pattern forming member being integrally movable with said substrate stage.

29. The exposure apparatus according to Claim 28, wherein said exposure apparatus further comprises a control unit which measures a light intensity distribution corresponding to aerial images of various mark patterns using said aerial image measurement unit and obtains optical properties of said projection optical system based on data of said light intensity distribution measured.

30. The exposure apparatus according to Claim 28, said exposure apparatus further comprising:

a mark detection system which detects a position of a mark on said substrate stage; and

a control unit which detects a positional relationship between a projected position of said mask pattern by said projection optical system and said mark detection system using said aerial image measurement unit.

31. An exposure apparatus that illuminates a predetermined pattern with an illumination light to transfer said pattern onto a substrate via a projection optical system, said exposure apparatus comprising:

a self-measurement master on which a plurality of types of measurement marks used for self-measurement are formed; and

a self-measurement master mounting stage on which said self measurement master is mounted, and which can move said self-measurement master close to a focal position on an object side of said projection optical system where said illumination light can illuminate.

32. The exposure apparatus according to Claim 31, said exposure apparatus further comprising:

an aerial measurement unit that includes a pattern forming member arranged within a two dimensional plane perpendicular to an optical axis of said projection optical system on which a measurement pattern is formed and a photoelectric conversion element which photo-electrically converts said illumination light via said measurement pattern; and

a driving unit which drives at least one of said self-measurement master mounting stage and said pattern forming member when at least a part of said self-measurement master is illuminated by said illumination light and an aerial image of said measurement mark illuminated by said illumination light is formed in a vicinity of a focal position on an image side

of said projection optical system by said projection optical system, so that said aerial image and said measurement pattern are relatively scanned.

33. The exposure apparatus according to Claim 32, wherein said measurement pattern includes at least one slit-shaped aperture pattern which width in a direction of said relative scanning is greater than zero, and equal to and under said wavelength λ of said illumination light divided by said numerical aperture N.A. of said projection optical system (λ/N.A.).

34. The exposure apparatus according to Claim 31, wherein said self-measurement master mounting stage is a mask stage on which a mask having said predetermined pattern formed is mounted.

35. The exposure apparatus according to Claim 34, said exposure apparatus further comprising:

a substrate stage where said substrate is mounted and a reference mark is provided;

an observation microscope to observe a mark located on said mask stage; and

a control unit which performs aerial image measurement of a measurement mark on said self-measurement master using said self-measurement master, said aerial image measurement unit, and said driving unit and calculates a magnification of said projection optical system based on said aerial image

measurement on exposing a first substrate of each lot, whereas on exposing a substrate besides said first substrate of each lot, said control unit observes a mark on one of said self-measurement master and said mask and an image of a reference mark on said substrate stage via said projection optical system using said observation microscope and calculates a magnification of said projection optical system based on a result of said observation, when said substrate is exposed by lot.

36. The exposure apparatus according to Claim 31, wherein said self-measurement master is a mask on which said predetermined pattern is formed.

37. The exposure apparatus according to Claim 31, wherein measurement marks formed on said self-measurement master include at least one of a distortion measurement mark of said projection optical system, a repetition mark for best focus measurement, an artificial isolated line mark for best focus measurement, an alignment mark for overlay error measurement with said substrate.

38. The exposure apparatus according to Claim 31, wherein measurement marks formed on said self-measurement master include an isolated line mark and a line and space mark having a predetermined pitch.

39. An adjustment method of a projection optical system

that projects a pattern on a first surface onto a second surface, said adjustment method including:

measuring optical properties of said projection optical system by an optical properties measurement method according to Claim 8; and

adjusting said projection optical system based on a result of said measurement.

40. An exposure method to transfer a pattern formed on a mask onto a substrate via a projection optical system, said exposure method including:

adjusting said projection optical system by an adjustment method of a projection optical system according to Claim 39; and

transferring said pattern onto said substrate using said projection optical system which optical properties have been adjusted.

41. A making method of an exposure apparatus that transfers a pattern formed on a mask onto a substrate via a projection optical system, said making method including:

measuring optical properties of said projection optical system by an optical properties measurement method according to Claim 8; and

adjusting said projection optical system based on a result of said measurement.

42. A device manufacturing method including a

lithographic process, wherein exposure is performed using said exposure apparatus according to Claim 28 in said lithographic process.

43. A device manufacturing method including a lithographic process, wherein exposure is performed using said exposure apparatus according to Claim 31 in said lithographic process.

add A.